

Information Summaries

IS-97/08-DFRC-SAW1

Sawtooth Climbs

Background

An airplane that is to fly toward a location that is some distance away must takeoff and climb to an altitude and speed where fuel consumption will be low during the cruise segment of the flight. The altitude and speed for best range will be identified by the Speed Power tests. It is important to identify the most efficient method for climbing to the cruise altitude, especially for jet aircraft where fuel consumption is quite high at low altitude. One test method for identifying the maximum rate of climb, and speed for best rate of climb, is the "sawtooth climb", a sequential series of climbs and dives performed at different, constant airspeeds. (The up and down, or "sawtooth" shape, of the flight path during these tests gives rise to its name.)

Sawtooth Climbs



1. Specific Objective of the Test

Determine the maximum rate of climb capability and the speed for best rate of climb at a particular altitude.

2. Critical Flight Conditions

There are several conditions that will influence the data collected during an accel.-decel. The important ones are:

- Altitude increment
- Wind speed and direction
- Atmospheric temperature
- Weight
- Configuration (flaps and landing gear position)

The altitude increment for the data collection will depend on the airplane's overall performance capability. For highly transient airplanes such as fighters, a fairly large altitude increment is required in order to minimize the sensitivity to time measurements. For transport-type aircraft a smaller altitude increment may be appropriate.

Since the tests will be flown at constant airspeed, the measurement of rate of climb will be affected by wind gradients, that is, changes in the wind speed or direction over the altitude increment of the test. Wind surveys (taken before the test using a balloon) are used to identify wind gradients and to select a test location or flight heading which will minimize wind effects. Sawtooth climbs at the lower altitudes are often flown over the ocean where smooth air and constant wind conditions exist.

The airspeed for best rate of climb may not be well predicted before the start of the test. It is therefore not uncommon to add additional test points as the test progresses in order to insure that there are sufficient data to properly identify the speed for best rate of climb.

3. Required Instrumentation

The parameters usually measured and recorded during sawtooth climbs are shown in Table (1-1). The engine instruments shown are representative but not complete. They will vary markedly depending on the type of engine. The engine instrumentation will be used to correct the rate of climb measurements to standard day pressures and temperatures by applying corrections for engine thrust.

A continuous time history of these parameters is desirable but not essential for these tests. Time and altitude measurements can even be recorded by a crew member in the airplane using a stop watch.

4. Starting Trim Point

The flight test engineer will establish a table of altitudes, altitude increments, and climb airspeeds where sawtooth climbs are to be performed. A typical sample table of flight conditions for sawtooth climbs is shown in Table (1-2).

A test begins with an initial trim point at the expected speed for best rate of climb and at the baseline altitude. The pilot establishes the airplane in level flight, then uses the trim devices in the airplane's control system to allow the airplane to continue in stable, level flight, but with the pilot's hands and feet off of the controls. A short data recording is taken of this condition, usually referred to as a "trim shot".

5. Description of a Sawtooth Climb

The pilot will descend to an altitude well below the starting altitude for the test, and insures that the heading is consistent with the minimum expected wind gradients. Maximum power is then established and the airplane is stabilized in a climb at constant airspeed, using only the pitch control to maintain the airspeed. Timing begins when the airplane passes through the lower altitude of the test altitude increment, and ends when it passes through the upper value of the increment. For the example shown, the time would be measured between 13,000 feet and 17,000 feet altitude. After passing through the upper altitude, the pilot will reduce the power to idle, and again descend to well below the lower end of the test altitude increment. Maximum power is again applied and the test is repeated but at a different climb airspeed.

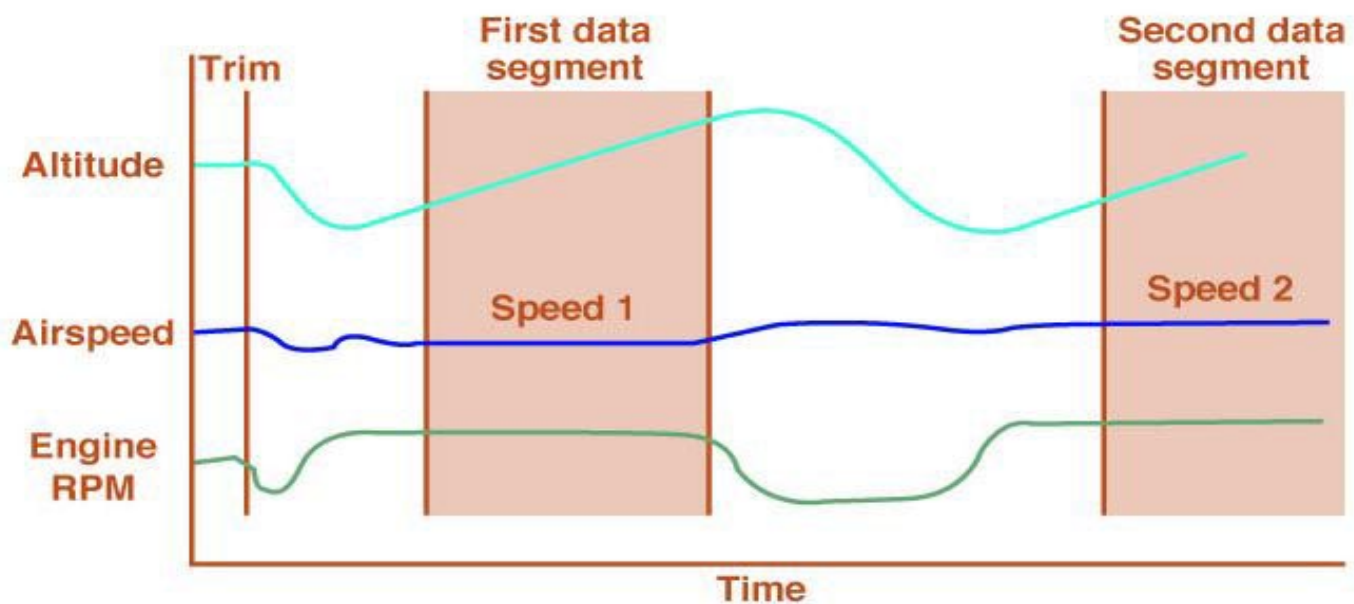


Sawtooth Climb Segment

6. Measures of Success

A successful series of sawtooth climbs will meet the following test criteria:

- All instrumented parameters recorded properly.
- Engine thrust and airspeed were both stabilized before reaching the lower band of the test altitude.
- Airspeed did not change more than 3 knots during the climb portion of each test.
- Data successfully crossplots with level flight accels.



A sample sawtooth climb is shown.

The results from each climb are calculated by dividing the altitude increment by the time required to climb through that increment:

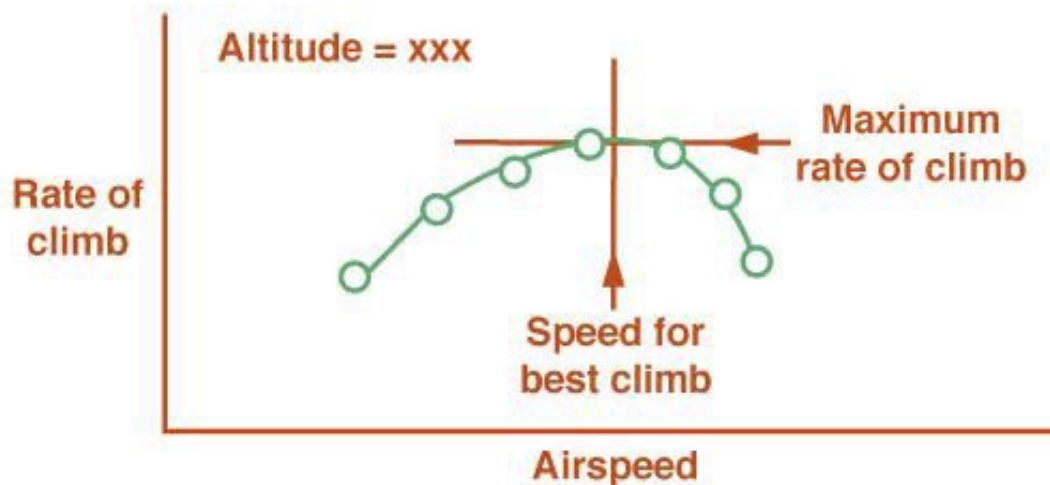
$$\text{rate of climb} = \left(\frac{dh}{dt} \right) = \frac{\Delta h}{\Delta t} = \frac{\text{alt. incr.}}{\text{time}}$$

For the example shown:

at 300 knots, time = 82 seconds

$$\frac{dh}{dt} = \frac{4000\text{feet}}{82\text{seconds}} \times \frac{60\text{seconds}}{\text{minute}} = 2927 \frac{\text{ft}}{\text{min}}$$

All of the climbs performed at a particular altitude are then plotted vs airspeed (see figure below). The peak of the curve is the maximum rate of climb capability of the airplane at the test altitude, and the airspeed corresponding with the peak of the curve is the airspeed of best rate of climb.



SAWTOOTH CLIMB TIME HISTORY

Table 1-1

Listing of Instrumentation Parameters

Parameter	Used for
Airspeed	Compute Mach and dyn. Pres.
Pressure Altitude	
Outside Air Temperature	
Time (to 1/100th second)	measure time to climb
Engine RPM	Thrust corrections to standard-day conditions
Engine tailpipe pres. & temp.	
Engine inlet pres. & temp	

Table 1-2

Table of Rate-of-Climb Test Conditions

Config.	Alt.	Trim Speed	Stabilized Climb Speeds - knts.
Clean	10000	300	240,260,280,300,340,360
	20000	300	
	30000	300	
	35000	300	
	45000	300	
Gear, Flaps	5000	160	130,140,150,160,170,180,190